Ripple Measurements on the Glassman LX125N16 High Voltage Power Supply for Lariat

Hans Jostlein August 8, 2014

Introduction

The Lariat experiment is designed to measure the response of a Liquid Argon Time Projection Chamber (LArTPC) to test particles of known species and momentum.

LArTPC's require a uniform electric drift field, typically imposed by a "field cage" enclosing the drift volume.

The field cage is typically composed of a series of equipotential "rings" (in the form of tubes or strips), each held at an appropriate potential.

The ring potentials are frequently established by connecting them sequentially to a chain of resistors that runs between the cathode and the anode of the TPC.

The Cathode voltage (and consequently the ring potentials) must be sufficiently stable and free of electric noise and ripple.

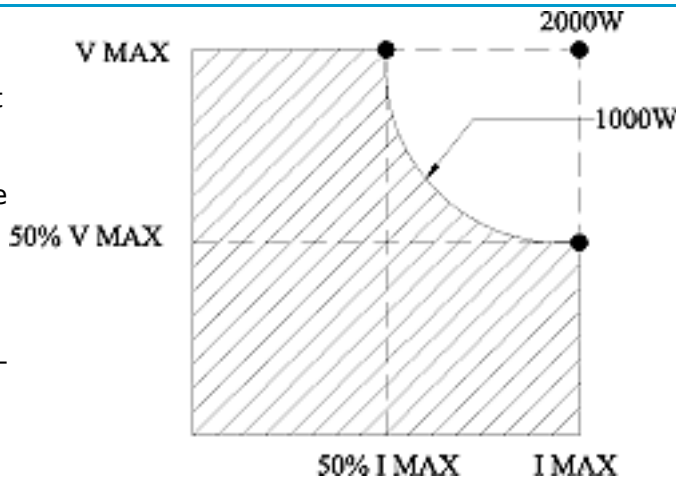
The stability requirement is not part of this note. Commercial supplies such as the one to be used at Lariat (0.005% voltage stability) are easily meeting requirements.

Any ripple from the HVPS can couple capacitively into the sensing wires and readout amplifiers. We have yet to measure that sensitivity. Once we know that, the ripple data presented here can be used to assess the level of any concern due to ripple.

Ripple Specification for the LX125N16 HVPS

The manufacturer (Glassman) specifies:

Features



***Extended Current.** LX models have maximum current ratings that are equivalent to a 2000W supply. These currents are available up to 50% of rated output voltage. Above this point, current is derated to maintain a constant 1000 W maximum output.

Pulse-Width Modulation. Off-the-line pulse-width modulation provides high efficiency and a reduced parts count for improved reliability.

Air Insulated. The LX Series features "air" as the primary dielectric medium. No oil or encapsulation is used to impede serviceability or increase weight.

Constant Voltage/Constant Current Operation. Automatic crossover from constant-voltage to constant-current regulation provides protection against overloads, arcs, and short circuits.

Low Ripple. Ripple is less than 0.03% of rated voltage at full load.

Tight Regulation. Voltage regulation is better than 0.005% for allowable line and load variations. Current regulation is better than 0.05% from short circuit to rated voltage.

Front Panel Controls (Analog and Digital Versions.) Separate 10-turn controls with locking vernier dials are used to set voltage and current levels. A high voltage enable switch and an AC power on/off switch complete the panel controls. L.E.D.'s indicate when high voltage is on, the output polarity, and whether the supply is operating in a voltage or current regulating mode. For the blank panel version, only a power on/off switch is provided on the panel.

Small Size and Weight. LX Series power supplies occupy only 8.75 inches of panel height. Net weight is less than 47 pounds.

Warranty. Standard power supplies are warranted for three years; OEM and modified power supplies are warranted for one year. A formal warranty statement is available.

Specifications

(From 5 to 100% of rated voltage. All units operate down to zero output with very slight degradation of performance.)

Input: 102-132V RMS, single-phase, 48-63Hz, <20 A. A 3-position terminal block with protective cover is provided.

Efficiency: Typically 85% at full load.

Output: Continuous, stable adjustment, from 0 to rated voltage or current by panel mounted 10-turn potentiometers with 0.05% resolution, or by external 0 to 10V signals is provided. Linearity is <1% of rated. Accuracy is 1% of rated + 1% of setting. Repeatability is <0.1% of rated.

Stored Energy: 60kV: 15J; 125kV: 30J.

Voltage Regulation: Better than 0.005% for specified line variations and 0.005% + 1 mV/mA for load variations.

Ripple: <0.03% of rated voltage + 1V RMS at full load (0.1% for 150 kV).

Current Regulation: Better than 0.05% from short circuit to rated voltage at any load condition.

Voltage Monitor: 0 to +10V equivalent to 0 to rated voltage. Accuracy, 1% reading +1% rated.

Current Monitor: 0 to +10V equivalent to 0 to rated current. Accuracy, 1% reading + 0.1% rated for single polarity, 1% reading + 0.15% rated for reversible polarity.

Stability: 0.01% per hour after 1/2 hour warmup, 0.05% per 8 hours.

Voltage Rise/Decay Time Constant: 50 ms typical to 60kV (400 ms for higher voltages) with a 30% resistive load using either HV on/off or remote programming control.

Temperature Coefficient: 0.01% per degree C.

Ambient Temperature: -20 to +40 degrees C, operating; -40 to +85 degrees C, storage.

Polarity: Available with either positive, negative, or reversible polarity with respect to chassis ground.

Protection: Automatic current regulation protects against all overloads, including arcs and shorts. Fuses, surge-limiting resistors, and low energy components provide ultimate protection.

Accessory: Detachable 8-foot HV cable. See models chart for cable type.

Remote Controls: Terminal block is provided for all remote functions, including common, +10V reference, interlock, voltage and current program/monitor, HV Enable/Disable, ground, and local control.

External Interlock: Open off, closed on. Normally latching except for blank panel version where it is non-latching.

HV Enable/Disable: 0-1.5V off, 2.5-15V on.

Measured Ripple

The ripple is specified as no more than 0.03% of the high voltage plus 1 Volt at full voltage and rated current. For 125 kV setting that would be 38.5 V ripple.

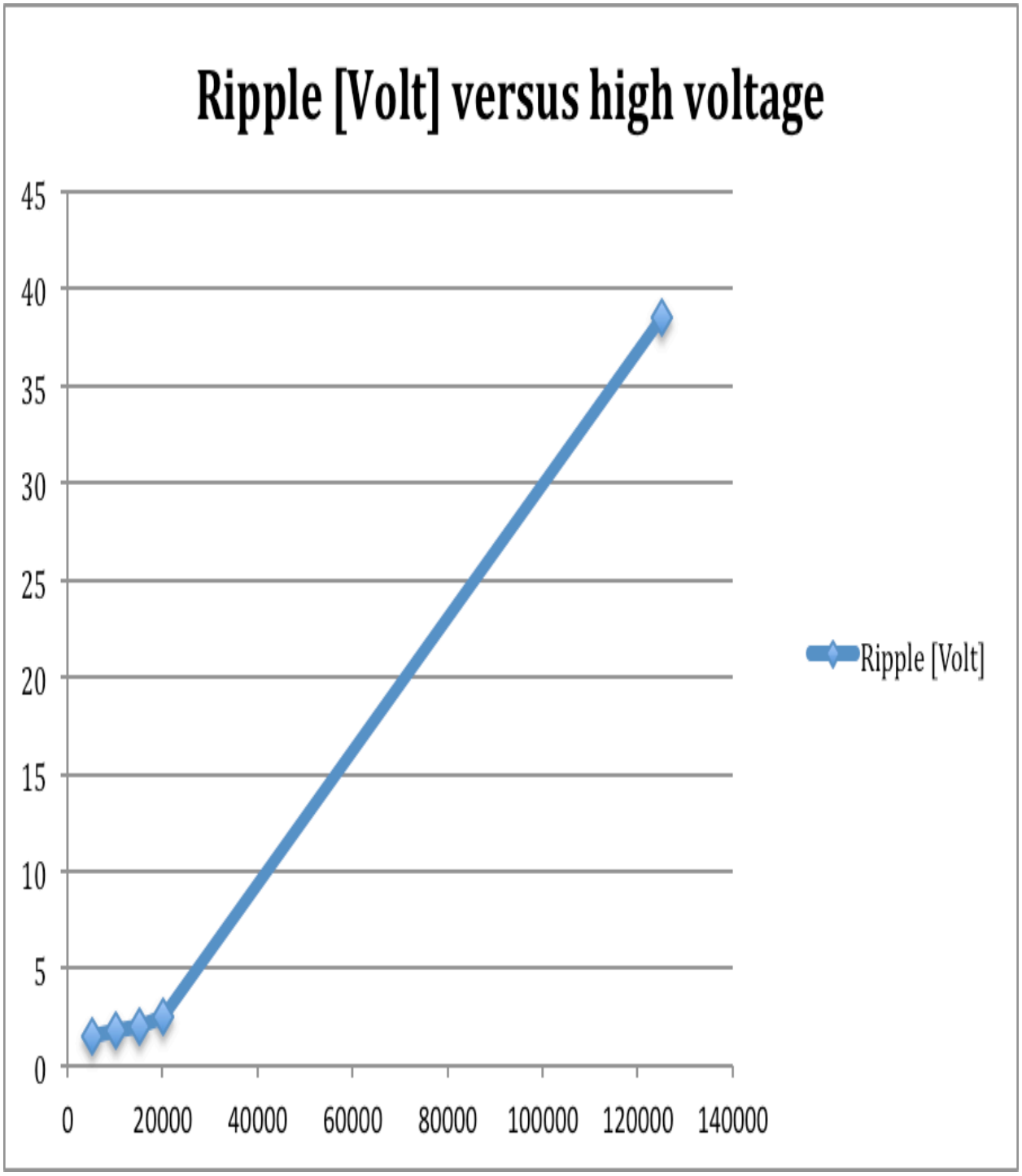
Lariat will operate at a lower voltage (25 kV) and much smaller output current . The current will be (500 V) / (250 MOhm) = 2 microamps.

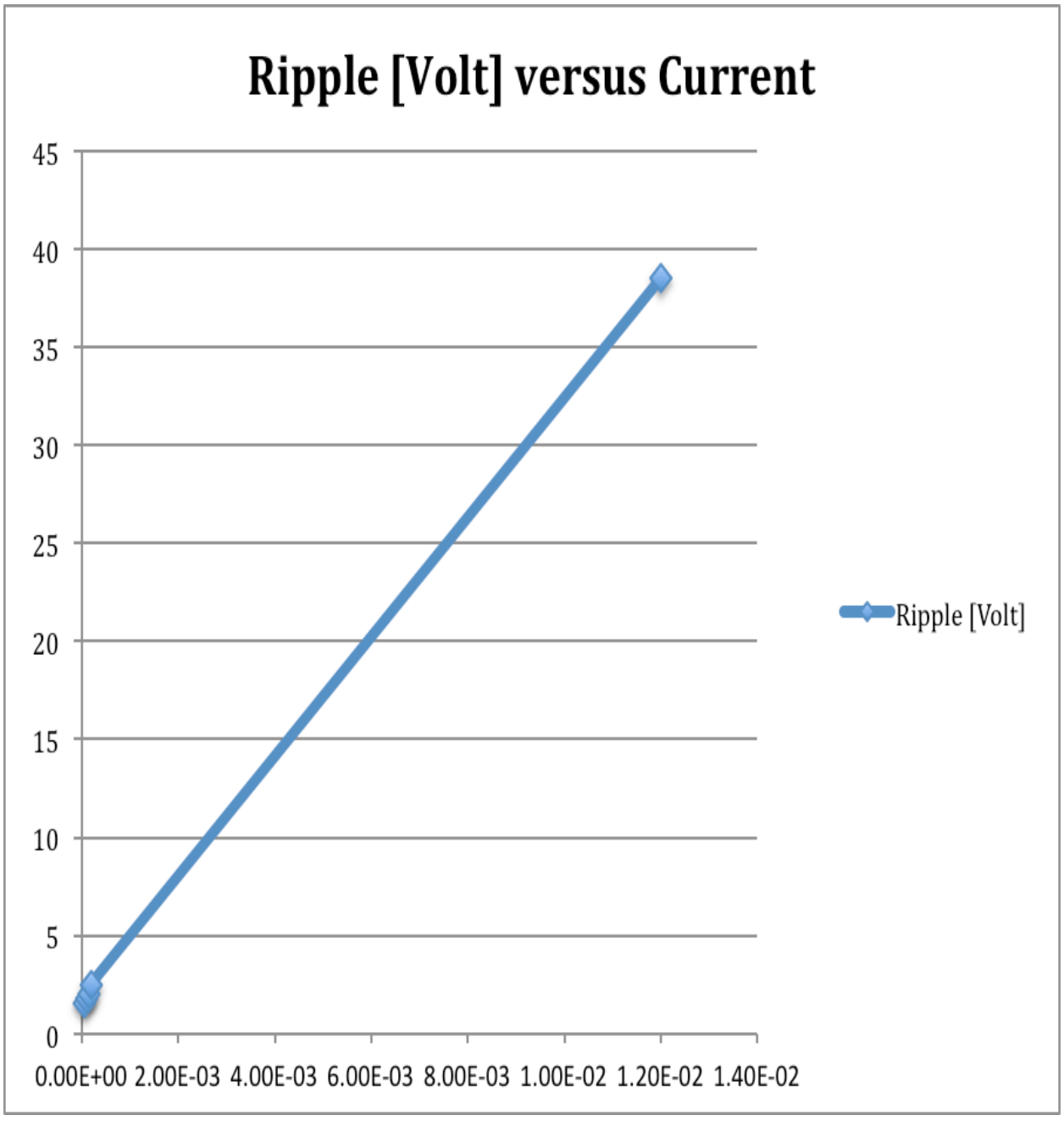
While the 38.5 V number may be low enough after the low-pass filters, We decided to measure the ripple at small currents.

After some confusing results obtained from a custom board using HV capacitors and a resistive divider we used a commercial Tektronix model P 6015 probe. This probe loads the circuit with 100 MOhm. It has a bandwidth of about 50 MHz, much faster than required.
The maximum DC voltage rating is 20 kV, limiting the range of voltages we could look at.
We took data at 5kV,10kV,15kV and 20 kV.
The observed ripple was roughly a series of square waves with some small oscillations at the transitions.
The waves repeated after each 28 microseconds.
Their peak-to-peak voltages are in this table:

Test Volts [Volt]	Current [A}	Ripple [Volt]
5000	5.00E-05	1.5
10000	1.00E-04	1.8
15000	1.50E-04	2
20000	2.00E-04	2.5
125000 (spec)	1.20E-02	38.5

These results are plotted below:


Ripple [Volt] versus high voltage
45
40
35
30
25
20
15
10
5
0
0
20000
40000
60000
80000
100000
120000
140000
Ripple [Volt]


Ripple [Volt] versus Current
45
40
35
30
25
20
15
10
5
0
0.00E+00
2.00E-03
4.00E-03
6.00E-03
8.00E-03
1.00E-02
1.20E-02
1.40E-02
Ripple [Volt]

Interpretation of the Measurement Results

We find rippple voltages generally to be well below the specification, and below 2.5 V. Since the load was a fixed 100 MOhm, voltage and currebnt are proportional. While the data look roughly linear, it is not clear how one would extrapolate back to a current as small as the expected Lariat draw.

Luckily it is not important.
We show below the transmission of AC through the first filter (40 Megohm) pot and the 120 ft cable (12 nF) for three frequencies:

Attenuation:

After pot 1:

R [ohm]	4.00E+07
Cable cap{F}	1.20E-08
Time constant [s]	4.80E-01

Frequency [Hz]	Transmission factor	Ripple[V]
1.00E+04	2.08E-04	2.08E-04
1.00E+05	2.08E-05	2.08E-05
1.00E+06	2.08E-06	2.08E-06

The resulting ripple voltages (even before the action of the second filter pot are extremely small, and highly unlikely to be detectable by the wire readout system.

Conclusion

We measure the Ripple from the Lariat HV power supply.
We find that the remaining ripple after just the first stage noise filter will be less than 0.2 mV. We expect no detectable effects of this noise on the wire amplifiers.